Factors Influencing the Temporal and Spatial Variability of the Textural Characteristics of Event-Scale Strata on the Eel Shelf

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Contract #: N00014-99-C-0165

LONG-TERM GOALS

The overall goal of the STRATAFORM project is to advance our understanding of the development of stratigraphic sequences on continental shelves and slopes. Part of this understanding comes from detailed measurements of the characteristics of event-scale strata that may be formed or modified during river floods or intense storms. The research described below is directed toward providing data on the grain-size characteristics of event-scale strata that can be related directly to storms or floods observed during STRATAFORM. This information will provide a "yardstick" with which to examine older (prehistoric) sediment units in long cores with the objectives of understanding modes of deposition, strata preservation and, potentially, any long-term changes in the local climate or river discharge. Additionally, the sediment data are being used in conjunction with measurements of bottom boundary layer flows to validate and provide inputs and "ground-truth" for sediment transport and strata development models.

OBJECTIVES

Specific goals of this effort are:

1) Understanding of the scales of along-shore and cross-shore spatial variability associated with the sediments at several locations in the depth-zone where nearshore sands interfinger with mid-shelf muds (i.e., between about 40 and 70 meters on Eel shelf). Our grain-size data will be merged with x-radiographs and porosity data that have been collected by STRATAFORM colleagues to describe the variability of the shallow stratigraphy on Eel shelf.

2) Carry out detailed textural analyses of storm-generated, coarse-grained layers.

3) Continue to monitor the evolution of the record 1995 and 1997 flood layers to develop a quantitative understanding of how these event-scale strata are changed during burial. Develop flood and storm layer “signatures”.

4) Provide detailed grain-size analyses of sediments recovered in vibra-cores, piston cores and “slow-cores” in support of our research and the research of Drs. Nittrouer, Sommerfield and Borgeld. We seek a long-term perspective that can be examined in terms of controlling factors such as climate change or variations in the sediment discharge of the Eel River. When combined with time markers (e.g., ^{210}Pb and C^{14}), the sediment data allow budgets to be

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **Factors Influencing the Temporal and Spatial Variability of the Textural Characteristics of Event-Scale Strata on the Eel Shelf**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Drake Marine Consulting,1711 Quail Hollow Road,,Ben Lomond,,CA,95005**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

calculated over significant portions of the Holocene. Also, correlation with acoustic layers in high-resolution seismic profiles will be attempted.

Information from items 2 and 3 are important for the transport modeling that is being done by other components of STRATAFORM (e.g., Drs. Wiberg, Harris, Swift and Fan). Item 4 will be directly useful in assessing the fate of sediment introduced by Eel River.

APPROACH

A large collection of sub-samples is available for various sites from February 1995 through April 2000. We have routinely collected samples of the surface (0 - 1 cm) sediment at most regional sites on the shelf and, at selected sites (e.g., the O - line stations), we have taken multiple sub-cores of box cores and also collected piston cores. Rapid response sampling has been used to collect event layers.

The great analysis speed and resolution provided by the Coulter Counter Multisizer II, along with its ability to analyze very small samples, allows us to examine core sediments at closely - spaced intervals (1 cm or less). This is important because event-scale strata are typically less than 5 cm thick on this shelf. In addition, one of our objectives is to provide detailed grain-size data to help interpret the bulk density profiles generated by the new Geotek whole-core logger.

Spatial variability of sediment properties is important to sediment transport modelers and to understanding acoustic reflections from the seafloor. Cores collected in July 1997 will be part of a statistical analysis led by STRATAFORM investigator J. Goff (UTIG).

WORK COMPLETED

In research completed prior to FY00, Dr. Drake and his STRATAFORM colleagues have: 1) examined the characteristics of flood sediments that were deposited after major floods in 1995 and 1997 (Wheatcroft et al, 1998); 2) studied the changes to those sediment units caused by physical processes and bioturbation (Drake, 1998; 1999; Drake et al., 1998); 3) provided regional-scale sediment texture information (Drake, 1999) that has been used to assist in interpretation of acoustic reflectivity data and also has been used to "ground-truth" the predictions of the sediment transport modeling group (Drs. Wiberg, Harris and Swift); and, 4) examined the spatial variability shown by a collection of box core samples that were taken as a prelude to the full spatial study of July 1997 (Drake, 1997). The STRATAFORM project has produced the first comprehensive set of information on the characteristics of event-scale strata on any continental shelf (Wheatcroft et al., 1997; Drake et al, 1998; Drake, 1999; Hill et al., 1998).

Key results are:

- Demonstrated the ability to quantitatively inventory and, therefore, monitor the fate of *individual grain-size fractions* on the mid-shelf (Drake, 1999; Drake and others, 1998). Temporal changes in grain-size distributions have shown that fine-grained, highly porous flood sediment was not eroded by large storm waves that should have exceeded threshold stress levels on the mid-shelf. This finding has been critical to the proper modeling of across-shelf sediment transport by Drs. Wiberg and Harris. It has prompted a close look at the early changes in compaction and cohesiveness of event layers by Dr. Wiberg.

- Initially, spatial variability of grain-size was extremely small in the 1995 flood layer, indicating deposition from a highly flocculated suspension (see also Hill et al., 1998). Subsequent monitoring showed that physical reworking and bioturbation (Drake, 1999) produced coarsening and *mass increases*. There was no evidence for erosion of the flood layer on the mid-shelf.

- This result suggested that a part of the 1995 and 1997 flood sediment had temporarily accumulated on the inner shelf beneath turbid plumes and this sediment was added to the mid-shelf layer over subsequent months, coarsening the layer and producing an inverse grading. The data suggested that the inner shelf (depth < 50m) might be an important site of temporary storage of fine flood sediment. This reservoir could account for some portion of the "missing" flood sediment determined by the work of Wheatcroft and others (1997).

- Spatial variability (scales of 10's of meters) of grain-size increased rapidly at the surface of the 1995 flood sediment because of physical addition of sediment from the inner shelf during storms.

RESULTS

During FY00 we have focussed our attentions on, 1) completing the grain-size analysis of the 1997 spatial variability samples and delivering those data to Dr J. Goff, 2) analyzing the grain-size data for piston cores collected at site O-60 and O-70, 3) continuing our study of the modifications of event strata by bioturbation and storms, and 4) continuing to provide sediment data to support the work of the transport modelers. All of these objectives were successfully completed and they will be the subjects of presentations by Drs. Goff, Sommerfield, Drake and Fan at the Fall meeting of the AGU, December 2000.

In addition, we expanded our research objectives in FY00 by collecting and analyzing the sediments in event-scale layers that occur in the Rio Dell Formation at Centerville Beach in Fortuna CA, believed by Dr. Elana Leithold (NCSU) to be a Pliocene/Pleistocene analogue for the modern Eel shelf. Exciting progress has been made during FY00 in describing the characteristics of storm event layers produced in the winter of 1999/2000 on Eel shelf and comparing those characteristics to storm event beds in the Rio Dell Formation. Heretofore, the STRATAFORM project had collected an abundance of information on flood event layers, but relatively little information on the products of intense storms. Fortunately, this changed when Dr. Borgeld and his students at HSU collected four box cores at sites O-60, O-70, S-60 and K-60 in April 2000, after ONR funding for field work had ended. X-radiographs of those cores indicated significant changes in the nature of the strata near the seafloor; fresh, ripple cross-bedding was present in storm layers at the sediment surface. Also, Dr. Ogston (UW) told us of a particularly intense storm that her benthic tripod had recorded at S-60 in winter 1999/2000.

The results of our Coulter Counter analysis of the new storm deposits on the mid-shelf and similarly ripple cross-bedded event layers in the Rio Dell Fm are presented in the following graph (Figure 1). The grain-size distributions of the modern storm bed at site O-60 and the storm bed in the Rio Dell Fm are essentially identical. Both are well-sorted, sandy coarse silts with relatively little clay content. Storm beds at the 60 meter sites are strikingly similar to the rippled Rio Dell layer, whereas the storm bed at site O-70 is somewhat finer-grained, an expected consequence of the decline in wave-generated bottom currents with increasing shelf depth.

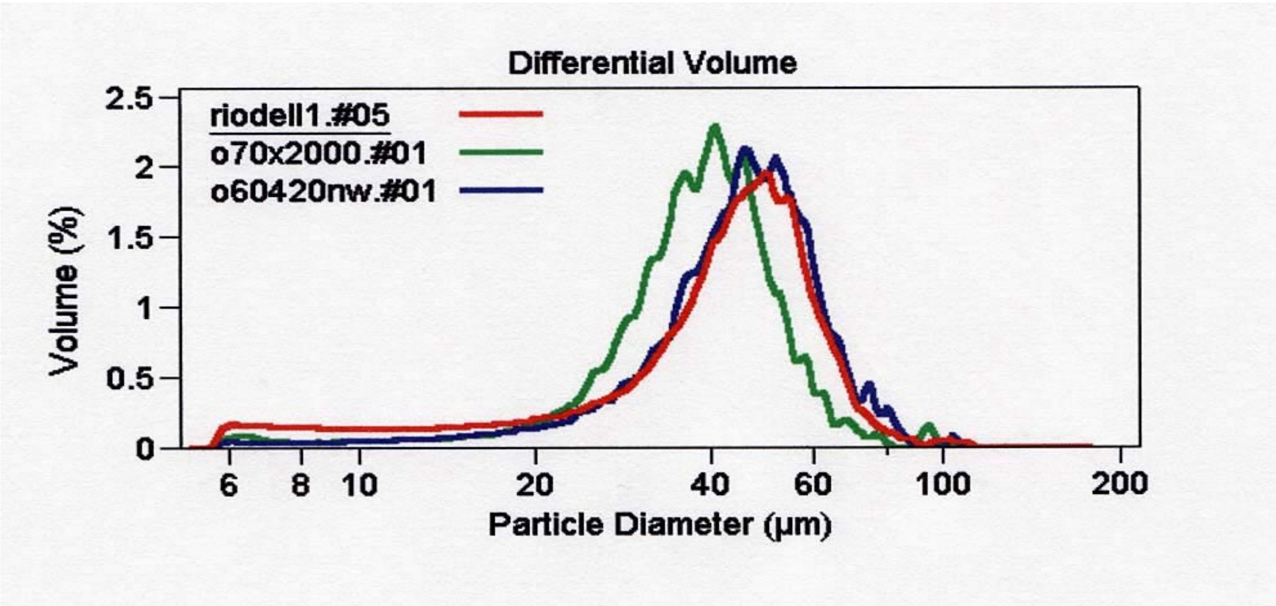

Figure 1. Grain-size distributions of ripple cross-bedded storm event layers in the Pliocene Rio Dell Formation (red) and at Site O-60 (blue) and Site O-70 (green) on the modern Eel shelf.

The ripple cross-bedded layer in the Rio Dell Fm is about 8 cm thick and it is immediately overlain by a thicker fine-grained layer that is thought to have been a flood event layer; the grain-size of this ancient flood layer compares favorably with that of modern Eel flood layers. However, distinct event layers are quite rare in the excellent outcrops of the Rio Dell. We began to suspect that the flood layer above the rippled storm bed had accumulated essentially instantaneously and had effectively preserved the storm layer by burying it to below the depth of most intense bioturbation (about 10 cm). If this had not occurred, we believe that the ancient, ripple cross-bedded unit would have been quickly destroyed by mixing. Thus, the usual products of intense storms may not be rare in the geologic record because of a lack of formation (i.e., a scarcity of storms), but rather because of a simple lack of preservation. Since even the most intense storms produce layers that are only a few centimeters (<5 cm) thick on the mid-shelf (Wiberg and Harris, personal communication), it follows that few or none will be preserved unless another event layer of substantial thickness is rapidly deposited over the storm bed.

Extending this hypothesis to the modern Eel shelf suggests a partial explanation for the distribution of event layers that we have begun to find in the 4-meter piston cores at O-60 and O-70. Storm event layers are rare in those cores (to ages of about 800 yBP), and flood event layers are common only in the sediment deposited in the most recent 50 years and near the base of the cores at about 700 yBP. There are stretches of hundreds of years with no distinct storm or flood units preserved. It is most unlikely that there were no strong storms during those centuries. The absence of storm beds suggests that there were relatively few flood events to elevate shelf sedimentation rates to the levels needed to insure storm bed preservation. Dr. Wheatcroft (OSU) and I will be examining the rates that are needed to preserve the grain-size signatures of the event-scale beds when the bed is being continuously mixed by the infauna. We note that most shelves have sedimentation rates that are less then the long-term rate on Eel shelf and, therefore, we expect storm event strata to be rarely preserved on most shelves.

IMPACT/APPLICATIONS

Future impacts related to our findings are: 1) Broad changes in the character of shelf sediment can occur on time scales of hours to days during and following floods and storms. Rapid response sampling *and* much more sophisticated *in situ* sampling are required to understand these changes. 2) The physical properties of the bed (e.g., texture, compaction and cohesiveness) must be known if modeling of sediment transport is to be accurate. 3) Our understanding of the stratigraphic column depends on the quality of the standards that we have. If recent systems are different because of man's activities or other factors, these influences must be quantified through careful study of long cores. STRATAFORM research has spot-lighted the critical need for high-quality 50m - 100m cores on the margin. 4) We have demonstrated the usefulness of very detailed grain-size profiles in cores. It is not uncommon to find that grain-size data at downcore intervals of 0.5 cm can reveal strata that are not readily detected by either x-radiographs or the Geotek whole-core logger.

TRANSITIONS

Event-scale strata are the building blocks of the stratigraphic column on Eel shelf. Our results provide fundamental information for the modeling components of the STRATAFORM project. Drs. Harris, Wiberg and Swift have used our data on flood layer modifications, both as inputs to begin their modeling predictions but also as "ground-truth" to check their results. Based on our data, Wiberg has modified her approach to incorporate bed cohesiveness more prominently on the mid-shelf. Spatial scales are also important for the stratigraphic modelers and the spatial variability results (Goff and others, 2000) will be useful.

The speed of the Coulter Counter has allowed closely spaced sediment analyzes in long cores to help interpret the variations detected by the Geotek core logger (Drs. Nittrouer and Sommerfield). This will be important for sorting out the question of whether recent strata on Eel shelf are representative of long-term conditions.

The studies of time and space variability have been important as a catalyst for new ideas on how to properly sample events that may last for only a few hours or days. I am sure that new *in situ* sampling methods, such as those proposed by Dr. Wheatcroft, will be the outcome of this work.

RELATED PROJECTS

The seabed sampling components are all interrelated, and data exchanges occur frequently. The research of Drs. Wheatcroft, Borgeld, Drake and Sommerfield are especially related because of the common objectives of providing full descriptions and understanding of the strata on Eel shelf. Dr. Drake also contributes to the sediment transport modeling effort of Drs. Wiberg, Harris, Fan, Swift, Sternberg, Cacchione and Ogston; journal articles are planned that will relate the event-scale strata to the waves and currents on the shelf. Further comparison of modern deposits with those of the Rio Dell Formation will also be pursued with Dr. Leithold. Finally, the spatial variability study will involve close cooperation with Dr. Goff (UTIG).

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